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Combining ability analysis for within-boll yield components in upland cotton (*Gossypium hirsutum* L.)

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ABSTRACT. Cotton is an important cash crop worldwide, accounting for a large percentage of world agricultural exports; however, yield per acre is still poor in many countries, including Pakistan. Diallel mating system was used to identify parents for improving within-boll yield and fiber quality parameters. Combining ability analysis was employed to obtain suitable parents for this purpose. The parental genotypes CP-15/2, NIAB Krishma, CIM-482, MS-39, and S-12 were crossed in complete diallel mating under green house conditions during 2009. The F_0 seed of 20 hybrids and five parents were planted in the field in randomized complete block design with three replications during 2010. There were highly significant differences among all F_1 hybrids and their parents. Specific combining ability (SCA) variance was greater than general combining ability (GCA) variance for bolls per plant (9.987), seeds per boll (0.635), seed density (5.672), lint per seed (4.174), boll size (3.69), seed cotton yield (0.315), and lint percentage (0.470), showing predominance of non-additive genes; while seed volume (3.84) was controlled by additive gene action based on maximum GCA variance. Cultivar MS-39 was found to be the best general combiner for seed volume (0.102), seeds per boll (0.448), and lint per seed (0.038) and its utilization produced valuable hybrids, including MS-39 x NIAB Krishma and MS-39 x S-12. The parental line CIM-482 had high GCA effects for boll size (0.33) and seeds per boll (0.90). It also showed good SCA with S-12 and NIAB Krishma for bolls per plant, with CP-15/2 for boll size, and with MS-39 for seeds per boll. The hybrids, namely, CP-15/2 x NIAB Krishma, NIAB Krishma x S-12, NIAB Krishma x CIM-482, MS-39 x NIAB Krishma, MS-39 x CP-15/2, and S-12 x MS-39 showed promising results. Correlation analysis revealed that seed cotton yield showed significant positive correlation with bolls per plant, boll size and seeds per boll while it showed negative correlation with lint percentage and lint per seed. Seed volume showed significant negative correlation with seed density. Seeds per boll were positively correlated with boll size and negatively correlated with bolls per plant lint percentage and lint per seed. Similarly, lint per seed exhibited positive correlation with lint percentage and boll size showed significantly negative correlation with bolls per plant. Presence of non-additive genetic effects in traits like bolls per plant, seeds per boll, lint per seed, seed cotton yield, and lint percentage is indicative of later generation selection or heterosis breeding may be adopted. For boll size, seed volume and seed density early generation selection may be followed because of the presence of additive gene action. The parental material used in this study and cross combinations obtained from these parents may be exploited in future breeding endeavors.

Key words: Cotton; GCA; SCA; Bolls per plant; Non-additive; Conventional breeding

INTRODUCTION

Cotton is an important fiber crop and grows on an area of 34 million ha in more than 50 countries of the world (Smith and Coyle, 1997). The genus *Gossypium* consists of 45 diploid and 5 allotetraploid species and is the 6th major source of edible oil production in the world (Ulloa, 2006). More than 80% of world's cotton area is cultivated by tetraploid species. About 26.247 million metric tons of cotton is produced globally, and China has maximum production of yield on a per acre basis, that is 1265 kg/ha, among the major cotton-growing countries (Khadi et al., 2010). However, in Pakistan, the productivity level is about 695 kg/ha (Anonymous, 2009). To compete with the modern world and fulfill the fiber demand, it is necessary to increase the productivity of cotton on a per acre basis. To enhance productivity, conventional breeding procedures have been implemented in recent years (Rathore et al., 2008; Schwartz and Smith, 2008). Many factors are related with increase in cotton production. Coyle and Smith (1997) stated that cotton breeders usually focus on increasing the number of bolls/unit area as a method of increasing the yield/unit land area. Waldia et al., in 1980, reported a greater magnitude of specific combining ability (SCA) variance for seed cotton yield, bolls per plant, and boll weight than general combining ability (GCA) variance; this implied that the action of non-additive genes controls these traits. Ahuja and Dhayal (2007) depicted that bolls per plant, boll weight, and seed cotton yield were controlled by non-additive gene action. On the other hand, Kumaresan et al. (1999) reported that both additive and non-additive genes were important for controlling boll number and seed cotton yield. Seed volume and seed density are important for an increase in seed vigor and thereby influence seed cotton yield (Ferguson and Turner, 1971). Worley et al. (1974) reported that the boll number per unit of land area is an important factor for increasing the yield, followed by seeds per boll and lint weight per seed. Culp and Harrell (1975) stated that a higher lint percentage supports higher lint yield and that lint yield is influenced by the selection of boll size and seed size. Harrell and Culp (1976) reported that to increase the surface area for lint production within-boll, the number of seeds per boll should be increased. They further concluded that the breeder should select for bolls per unit land area, maximum seeds per boll, higher seed surface area, and maximum lint weight per unit seed surface. Ragsdale and Smith (2007) concluded that fiber production is increased by enhancing the uniform size of seed and rate of fibers on the surface of the seeds. Coyle and Smith (1997) reported that genotypes with positive effects on the GCA for fiber quality had negative effects on GCA for basic within-boll yield components. They concluded that simultaneous improvements in multiple yield components will facilitate an increase in yield by using straight-forward selection parameters. Green and Culp (1990) found significant GCA effects for fiber length, fiber strength, length uniformity, and lint yield per unit land area. Basal et al. (2009) determined that the major problem with the simultaneous improvement of yield with higher fiber quality is the negative association between lint yield components and the fiber quality parameter because of linkage and pleiotropic effects. For the development of plant material that holds good promise for the plant breeder, the proper selection of parents for hybridization is important. No study has yet determined the potential of a local germplasm source to improve the within-boll yield components in the best cotton genotypes. Analysis of combining ability enables cotton breeders to better understand the genetic basis on which certain parental lines can be exploited in the breeding program (Zhang et al., 1994; Braden et al., 2003). The objective of this research was to evaluate whether within-boll yield components can be potentially improved by estimating the GCA and SCA effects, as defined by Sprague and Tatum (1942), and reciprocal effects, as defined by Griffing (1956; Method-I, Model-II).

MATERIAL AND METHODS

The present study was conducted at the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, during the year 2009-2010. The plant material used was developed by crossing different varieties, viz., CP-15/2, NIAB Krishma, CIM-482, MS-39, and S-12. The 5 parents were grown under controlled conditions in a glasshouse during the month of November 2009. Day and night temperatures in the glass house were maintained using steam and electric heaters. Day light during winter was supplemented by lighting mercury vapor lamps. When the parental lines started to flower, they were crossed in all possible combinations according to the diallel mating system. Several attempts were made to develop sufficient F_0 seed.

The F_0 seed of 20 hybrids and 5 parents were planted in the field on June 11, 2010. Each entry was sown in 3 replications by using the randomized complete-block design. Five plants were placed in each row. Row-to-row and plant-to-plant distance was maintained at 75 and 30 cm, respectively. Fertilizer and irrigation were not applied because of heavy rain during the entire cotton season. Attack of diseases was increased due to high humidity. Temperature was normal during the cotton-growing period. The climatic data were obtained from Agromet Bullet in Agriculture Meteorology Cell, Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan, which is located at latitude, 31°26'N; longitude, 73°06'E, and altitude, 184.4 m. A graph of the climatic conditions during the cotton-growing period is shown in Figure 1.

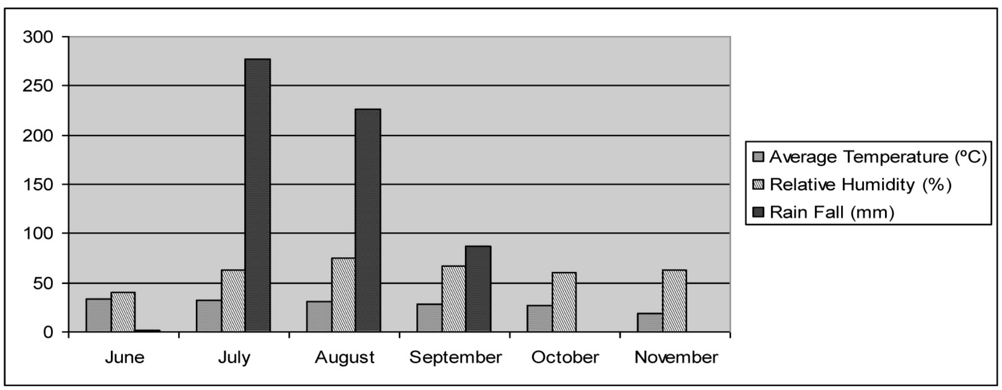

Figure 1. Climatic condition from June to November 2010.

At maturity, data for the middle row of 5 good healthy plants per replication were collected for bolls per plant, boll size, seed cotton yield, and lint percentage. Seed volume was determined by displacement in 50 mL ethanol by using a 100-seed sample. Seed density was calculated as the ratio of seed weight to seed volume. The following formulas were utilized in the U.T. Computing Center for calculations of the other yield components:

Seeds per boll = boll size (100 - lint%) / seed index

Lint per seed = seed cotton per seed x lint percentage

Seeds per boll and lint per seed were calculated according to the method described by Worley et al. (1974).

The total product of the plant was ginned, and the lint obtained from each sample was weighed to calculate lint percentage by the following formula:

$$\text{Lint percentage} = \frac{\text{weight of lint obtained in sample}}{\text{weight of seed cotton in sample}} \times 100$$

The data collected were subjected to analysis of variance (Steel et al., 1997) to determine the significance of differences among the genotypes for the plant traits under study. The characters showing significant genotypic differences were further analyzed for GCA and SCA effects, as defined by Sprague and Tatum (1942), and reciprocal effects, as defined by Griffing (1956; Method-I, Model-II).

RESULTS

Analysis of variance revealed highly significant differences among the parents and hybrids for all characters, thereby indicating the presence of genetic diversity among them (Table 1). SCA variance was greater than GCA variance for bolls per plant, boll size, seed density, seeds per boll, and lint percentage, which indicates non-additive type of gene action for these traits. Seed volume, lint per seed, and seed cotton yield showed high reciprocal estimates.

Table 1. Analysis of variance for various within-boll yield components in upland cotton.

Sources of variation	d.f.	B/P	BS	SV	SD	S/B	L/S	L%	SCY
Replication	2	0.223	0.142	0.051	1.106	4.803	3.037	3.062	0.766
Genotypes	24	0.399	0.152	0.141	2.777	8.455**	0.042	3.020**	5.406**
GCA	4	0.28**	5.26^{NS}	8.633**	1.441**	4.821*	2.793**	0.660^{NS}	1.931^{NS}
SCA	10	8.60**	3.31**	4.988**	1.112**	2.602**	1.092**	1.346**	1.313**
Reciprocal	10	0.12**	0.06**	0.029**	5.327**	2.234**	1.398**	0.806**	2.281**
Error	48	0.207	8.08	9.335	1.595	1.533	3.914	0.555	0.783
σ^2GCA		1.951	1.97	3.837	3.742	0.226	1.734	-6.484	0.064
σ^2SCA		9.987	3.69	2.413	5.672	0.635	4.174	0.470	0.315
σ^2 Reciprocal		2.597	2.05	9.887	1.865	0.350	5.033	0.129	0.748
σ^2 A		3.90	3.94	7.674	7.485	0.453	3.46	-0.129	0.128
σ^2 D		9.98	3.69	2.413	5.672	0.635	4.17	0.470	0.315

d.f. = degrees of freedom; B/P = bolls per plant; BS = boll size; SV = seed volume; SD = seed density; S/B = seeds per boll; L/S = lint per seed; L% = lint percentage; SCY = seed cotton yield; GCA = general combining ability; SCA = specific combining ability.

Significant GCA effects were detected for the within-boll yield component (Table 2). The estimated GCA effect for the 5 parents varied significantly for all traits. Among these genotypes, CP-15/2 was the best general combiner for improving lint per seed; NIAB Krishma for bolls per plant; CIM-482 for boll size, seed density, and seeds per boll; MS-39 for seed volume and lint percentage, and S-12 for seed cotton yield.

Table 2. Estimates of general combining ability effects for various characters of *Gossypium hirsutum* L. in a 5 x 5-diallel cross experiment.

Parents	B/P	BS	SV	SD	S/B	L/S	L%	SCY
CP-15/2	-0.218	-0.024	0.072	-0.007	-0.554	0.063	0.167	-0.648
NIAB Krishma	0.207	-0.112	-0.018	0.001	-0.780	-0.020	-0.203	-0.201
CIM-482	-0.043	0.33	-0.021	0.006	0.902	-0.007	-0.126	0.271
MS-39	-0.068	0.078	0.102	-0.015	0.448	0.038	0.369	0.281
S-12	0.123	0.025	-0.135	-0.021	-0.016	-0.073	-0.207	0.334
SE (g_i-g_j)	0.117	7.34	4.32	5.64	0.553	0.027	0.333	0.395

For abbreviations, see legend to Table 1.

The SCA effects showed that the best specific combinations were as follows: CIM-482 x S-12 for boll per plant; CP-15/2 x S-12 for boll size; NIAB Krishma x S-12 for seed volume; CIM-482 x S-12 for seed density; NIAB Krishma x CIM-482 for seeds per boll; CIM-482 x S-12 for lint per seed; CP-15/2 x NIAB Krishma for lint percentage, and CP-15/2 x S-12 for seed cotton yield (Table 3).

Table 3. Estimates of specific combining ability effects for various characters of *Gossypium hirsutum* L. in a 5 x 5-diallel cross experiment.

Genotypes	B/P	BS	SV	SD	S/B	L/S	L%	SCY
CP-15/2 x NIAB Krishma	-0.065	-0.031	-0.049	0.007	0.087	0.022	0.346	-0.084
CP-15/2 x CIM-482	0.102	-0.176	0.021	-0.011	-0.939	-0.054	0.294	-0.806
CP-15/2 x MS-39	-0.082	-0.054	0.031	0.001	0.887	-0.079	0.017	-0.508
CP-15/2 x S-12	0.102	0.229	0.101	-0.009	0.896	-0.068	-0.790	1.273
NIAB Krishma x CIM-482	-0.240	0.176	0.128	-0.019	1.543	-0.016	-0.355	0.678
NIAB Krishma x MS-39	-0.048	-0.006	-0.029	-0.007	-1.048	0.023	-0.188	-0.612
NIAB Krishma x S-12	-0.073	0.008	0.241	-0.032	0.669	0.013	-0.043	0.023
CIM-482 x MS-39	0.118	-0.049	0.091	-0.001	-0.670	0.043	-0.012	0.029
CIM-482 x S-12	0.343	0.003	-0.055	.010	-0.815	0.048	-0.353	0.705
MS-39 x S-12	-0.132	-0.028	0.071	-0.021	1.297	-0.090	-1.260	-0.118
SE (s_{ij}-s_{ik})	0.249	0.146	8.62	1.129	1.107	5.59	0.666	0.791

For abbreviations, see legend to Table 1.

Reciprocal effects (Table 4) indicated that the combination S-12 x CP-15/2 exhibited superiority in the number of bolls per plant, and the cross MS-39 x NIAB Krishma, for boll size. The cross S-12 x MS-39 produced the highest reciprocal effects, and the cross S-12 x CIM-482, for seed density. The crosses MS-39 x CP-15/2 and MS-39 x CIM-482 produced the highest reciprocal effects for seeds per boll and lint per seed, respectively. Similarly, the highest reciprocal effects for lint percentage and seed cotton yield were shown by the crosses NIAB Krishma x CP-15/2 and MS-39 x NIAB Krishma, respectively. The critical comparison of the combinations involving one parent with high GCA and the other with poor GCA provided an interesting result: the combination CIM-482 x NIAB Krishma was superior for boll size.

Table 4. Estimates of reciprocal effects for various characters of *Gossypium hirsutum* L. in a 5 x 5-diallel cross experiment.

Genotypes	B/P	B/S	SV	SD	S/B	L/S	L%	SCY
NIAB Krishma x CP-15/2	-0.083	0.008	-0.167	0.019	-0.855	0.160	1.015	-0.196
CIM-482 x CP-15/2	0.16	0.134	-0.100	0.013	0.932	-0.034	-0.492	1.204
MS-39 x CP-15/2	0.292	0.134	0.000	0.005	1.33	-0.087	-0.839	1.533
S-12 x CP-15/2	0.333	-0.500	-0.100	0.010	-1.87	0.015	0.442	-1.587
CIM-482 x NIAB Krishma	0.333	0.061	0.050	-0.000	0.776	-0.026	-0.203	1.296
MS-39 x NIAB Krishma	0.333	0.210	0.017	-0.005	0.565	-0.003	-0.632	1.758
S-12 x NIAB Krishma	-0.083	0.014	0.017	0.009	0.988	-0.047	0.076	-0.021
MS-39 x CIM-482	0.083	-0.045	-0.100	0.012	-1.495	0.165	0.872	-0.087
S-12 x CIM-482	-0.333	-0.027	-0.283	0.041	0.391	0.071	0.712	-0.475
S-12 x MS-39	0.167	-0.058	0.067	0.006	-0.060	0.014	0.384	0.213
SE (r_{ij}-r_{ik})	0.263	0.164	9.66	1.26	1.23	6.25	0.745	0.885

For abbreviations, see legend to Table 1.

Further investigation showed that in some combinations, both the parents had poor GCA, but they expressed appreciable performance in cross combinations: such combinations were NIAB Krishma x S-12 for seed volume, MS-39 x CP-15/2 for seed density, CP-15/2 x NIAB Krishma for seeds per boll, NIAB Krishma x S-12 for lint per seed, and S-12 x CIM-

482 for lint percentage. These results showed that for hybrid production, it is not necessary the parents possess better GCA since sometimes both parents with poor GCA may combine well to produce good hybrids. Similar results were found by Patel et al. (1997).

Correlation analysis

Correlation analysis is shown in Table 5, indicating that seed cotton yield showed significant positive correlation with bolls per plant (P ≤ 0.01), boll size (P ≤ 0.01), and seeds per boll (P ≤ 0.01), while it showed negative correlation with lint percentage (P ≤ 0.05) and lint per seed (P ≤ 0.05). Seed volume showed significant negative correlation with seed density (P ≤ 0.01). Furthermore, seeds per boll were positively correlated with boll size (P ≤ 0.01) and negatively, with bolls per plant (P ≤ 0.01), lint percentage (P ≤ 0.01), and lint per seed (P ≤ 0.01). Similarly, lint per seed exhibited positive correlation with lint percentage (P ≤ 0.01) and boll size showed significantly negative correlation with bolls per plant.

Table 5. Simple correlation analysis of traits in cotton genotypes.

Traits	B/P	BS	L%	L/S	S/B	SD	SV
BS	-0.3157**						
L%	-0.1348	-0.1737					
L/S	-0.1378	-0.1744	0.8371**				
S/B	-0.3342**	0.7409**	-0.3649**	-0.5470**			
SD	0.0897	0.0121	0.0020	0.0025	0.0028		
SV	-0.0427	-0.1099	-0.0431	-0.0588	-0.0696	-0.8781**	
SCY	0.2454*	0.7911**	-0.2564*	-0.2465*	0.6437**	0.0525	-0.1345

For abbreviations, see legend to Table 1. *,**Significantly at P ≤ 0.05 and P ≤ 0.01, respectively.

DISCUSSION

Significant genotypic differences among parents and their crosses for all the studied traits proved the presence of genetic variability. The genetic variability in each character was further explained by various reasons, such as the GCA and SCA, as defined by Sprague and Tatum (1942), and reciprocal effects, as defined by Griffing (1956; Method-I, Model-II).

The study of combining ability is useful to devise strategies for improving the hybrid performance of parental lines. The comparison of the performance of the 5 parents for their GCA showed that the parent CP-15/2 was the best general combiner for lint per seed. CIM-482 and NIAB Krishma were good general combiners for boll size, seed density, seeds per boll, and bolls per plant. MS-39 and S-12 were determined to be good combiners for seed volume, lint percentage, and seed cotton yield.

Bolls per plant are directly related to higher seed cotton yield (Ahmad et al., 2011) and were controlled by both additive and non-additive genes, as indicated by significant GCA and SCA mean squares. However, SCA variance was greater than GCA variance; therefore, non-additive gene action was more predominant than additive gene action. Therefore, heterosis breeding is recommended to increase the bolls per plant. Neelima et al. (2004), Ahuja and Dhayal (2007), and Basal et al. (2009) reported that non-additive gene action was more important for bolls per plant, while Tomer and Singh (1996) reported additive gene action. Kumaresan et al. (1999) reported that both additive and non-additive gene action were important for bolls per plant. NIAB Krishma and S-12 were good general combiners for bolls per plant and can be recommended for use in breeding programs to improve bolls per plant. CIM-482 x S-12 and MS-39 x NIAB Krishma had high SCA and reciprocal effects and can be used as a good hybrid for this trait. Increase in boll weight will increase the number of seeds per boll, which in turn will result in increased surface area, thereby enhancing the maximum lint percentage. However, breeding for increased boll weight only may not be sufficient. Breeding for increased boll weight, seeds per boll, seed size, and fiber mass per seed should also be considered along with boll weight because increased boll weight may also be due to increase in the number of seeds of a larger size, which will have a negative effect on lint yield. For boll weight, SCA variance was greater than GCA variance, but the genetic effect was controlled by additive gene action. Similar results were also found by Ahuja and Dhayal (2007), while Ahmad et al. (2001) and Mohamed et al. (2009) reported that additive gene action is important for boll weight. However, Neelima et al. (2004) and Kiani et al. (2007) reported that both additive and non-additive genetic variance was important in inheritance of boll weight and bolls per plant. CIM-482 is recommended for use in breeding programs to improve boll weight because it has a high positive GCA effect. NIAB Krishma x CIM-482, MS-39 x NIAB Krishma, and MS-39 x CP-15/2 had high positive SCA and reciprocal effects for boll weight and are recommended for hybrid breeding to improve this character.

Seed volume was controlled by both additive and non-additive type of genes, as indicated by highly significant GCA and SCA mean squares. However, GCA variance was greater than SCA variance, and therefore, additive gene action is more important than non-additive gene action. Simple selection method can be used to improve seed volume. Rahman et al. (2005) reported that seed volume was controlled by both additive and non-additive genetic effects. Contradictions to these results may be due to different genetic base of parent material and different environmental condition. MS-39 and CP-15/2 were the best general combiners for seed volume and recommended to be used in breeding programs to increase seed volume. NIAB Krishma x CIM-482 and S-12 x MS-39 had higher SCA and reciprocal effects for seed volume and can be used in heterosis breeding to improve this character. Seed density had both highly significant GCA and SCA mean squares, which means that both additive and non-additive genes control this trait. However, GCA mean square was greater than SCA mean square showing dominance of additive gene action. Therefore, the simple selection method can be used to improve seed density. CIM-482 and NIAB Krishma were good general combiners for seed density and can be used in breeding programs to improve seed density. NIAB Krishma x CP-15/2, MS-39 x CIM-482, and S-12 x CIM-482 had higher SCA and reciprocal effects and can be used for hybrid breeding to improve seed density.

Seeds per boll were controlled by both additive and non-additive type of genes, as indicated by significant GCA and highly significant SCA mean squares. SCA variance was greater than GCA variance, and therefore, non-additive type of gene action was more pronounced than additive gene action. Therefore, heterosis breeding is recommended to increase seeds per boll. Similar results were founded by Khan et al. (2009) and Singh et al. (1985) who have also reported non-additive gene action for seeds per boll. While Ahmad et al. (2001) had reported that additive gene action was important for seeds per boll. CIM-482 and MS-39 were good general combiners for seeds per boll and are recommended for use in breeding programs to improve this character. In case of seeds per boll, NIAB Krishma x CIM-482, CP-15/2 x MS-39, and MS-39 x CP-15/2 had higher SCA and reciprocal effects for number of seeds per boll and can be recommended for hybrid breeding. The mean squares of seed cotton per seed were non-significant under analysis of variance, suggesting that there was no significance difference among the genotypes for this character. Therefore, the data were not further analyzed using the Griffing approach (1956). Lint per seed had highly significant GCA and SCA mean squares, which means that both additive and non-additive genes control this trait. However, SCA mean square was greater than GCA mean square showing dominance of non-additive gene action. Therefore, heterosis breeding can be used to increase lint per seed**.** Similar results were founded by Coyle and Smith (1997) who have also reported the inheritance of non-additive gene action for lint per seed. They also showed that genotypes having good GCA estimates for fiber quality exhibited negative GCA for within-boll yield components, such as lint per seed and fiber per seed. CP-15/2 and MS-39 were good general combiners for lint per seed and can be recommended for breeding programs to improve this character. The crosses MS-39 x NIAB Krishma, MS-39 x CIM-482, and NIAB Krishma x CP-15/2 had higher positive SCA and reciprocal effects for lint per seed and can be recommended for hybrid breeding. For seed weight per seed, no significant difference was noted among the genotype; therefore, the data were not further analyzed using Griffing (1956) approach.

In this study, lint percentage was considered as a within-boll yield component and was estimated on an individual plant basis. Lint percentage had direct positive correlation with lint yield. Lint percentage had non-significant GCA and highly significant SCA mean squares. This implies that non-additive gene action was involved in controlling this trait. Therefore, hybrid development is recommended for improvement of the lint percentage. Previous studies by Iqbal et al. (2005), Rahman et al. (2005), Debaby et al. (1997), Patel et al. (1997), Neelima et al. (2004), and Inam-Ul-Haq and Azhar (2004) reported that lint percentage was controlled by non-additive gene action. While the results of Liu and Han (1998) and Green and Culp (1990) showed that inheritance of lint percentage was controlled by additive type of gene action. MS-39 and CP 15/2 had higher GCA effect for lint percentage. CP-15/2 x CIM-482 and NIAB Krishma x CP-15/2 proved to be good hybrids for improvement of lint percentage. Seed cotton yield had non-significant GCA and highly significant SCA mean square. This means that non-additive gene actions control this trait. Therefore, hybrid development is recommended for improvement of the trait. Inam-Ul-Haq and Azhar (2004) had reported that seed cotton yield were influenced by the genes acting non-additively, and in contrast, the studies of Kumaresan et al. (1999), Patel et al. (2009), and Laxman (2010) indicated that both additive and non-additive gene effects were important for controlling seed cotton yield. MS-39 x NIAB Krishma, MS-39 x CP-15/2, and MS-39 x NIAB Krishma showed higher SCA and reciprocal effects and were recommended for hybrid breeding to increase seed cotton yield.

CONCLUSION

In the present genetic investigation, the number of bolls per plant, seeds per boll, lint per seed, seed cotton yield, and lint percentage were conditioned largely by non-additive gene effects, suggesting the occurrence of hybrid vigor. Since the characters controlled by non-additive genes may have low heritability, which suggests that segregating populations are not amenable to selection pressure in early generations such as F_2, selection must be delayed until the genes are established in the breeding population or heterosis breeding may be adopted. Parents such as NIAB Krishma, CP-15/2, and MS-39 were good general combiners for most of the investigated parameters, and a few hybrids, namely, CP-15/2 x NIAB Krishma, NIAB Krishma x S-12, NIAB Krishma x CIM-482, MS-39 x NIAB Krishma, MS-39 x CP-15/2, and S-12 x MS-39 obtained from these parents showed promising results. These hybrids can be exploited in future breeding programs.

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